STRATAFORM Plume Study:
Analyses of Mooring Data and Associated Tasks

James F. Lynch
James D. Irish
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Tel.: (508) 289-2230, Fax: (508) 457-2194, Email: jlynch@whoi.edu
Tel.: (508) 289-2732, Fax: (508) 457-2154, Email: jirish@whoi.edu

N00014-97-1-0331

LONG-TERM GOALS

The overall goal of the ONR STRATAFORM program is to advance our understanding of the formation of stratigraphic sequences on continental shelves and slopes. Our research program focuses on identifying and quantifying sediment erosion, transport, and deposition processes on the continental shelf through state-of-the-art observational techniques in both fine grained and sandy environments. In sandy environments our goal is to understand the detailed interactions and feedbacks between hydrodynamics, bedforms, and the resulting sand transport. In fine-grained environments, such as the Eel River shelf, we have been investigating the role of fluid-mud flows as a cross-shelf transport mechanism.

OBJECTIVES

The primary objectives of this project are to analyze bottom boundary layer tripod data and water column mooring data taken during the winter of 1997-1998 at the Eel River STRATAFORM site. This site is particularly interesting because there is a large source of fine-grained sediment from the Eel River during winter flood events. The river plume has been shown to deliver sediment only to the inner shelf. However, the final deposit of the riverine sediment is located on the mid-shelf seaward of the 50 m isobath. Bottom tripod data has shown that a large amount of sediment, initially placed by the plume inshore of the mid-shelf patch, was transported seaward in the bottom boundary layer by low concentration suspended sediment transport forced by mean currents [*Cacchione et al*., 1998]. However, our acoustic backscatter sensor (ABS) combined with a vertical array of water velocity measurements revealed that during these periods of offshore transport of fine sediment from the inner shelf to the mid-shelf deposition area, high suspended sediment concentration layers form near the seabed. The data from our 1997-1998 deployment was used to examine the role of low concentration suspended sediment transport by mean currents vs. the role of down-slope flow of thin fluid-mud layers as cross-shelf transport mechanisms.

The second objective of our research program in 1999-2000 was to understand the dynamics of these thin, high concentration density flows through a combination of modeling and data analysis. Both the modeling and data analysis are also used to investigate the role of these flows in creating flood deposits.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **SEP 2000**	2. REPORT TYPE	3. DATES COVERED **00-00-2000 to 00-00-2000**

4. TITLE AND SUBTITLE **STRATAFORM Plume Study: Analyses of Mooring Data and Associated Tasks**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution,,Woods Hole,,MA,02543**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

The observational program consisted of a cross-shore array of (a) three bottom boundary layer monitoring tripods, and (b) three water column moorings, crossing the shelf from the inner shelf (20 m isobath) to the mud deposit region (60 m isobath). This array, combined with the rapid response program of Geyer et al., allowed simultaneous measurements of the water velocity and the vertical structure of sediment concentration in both the Eel River plume and the bottom boundary layer between the inner shelf and the deposit region.

The modeling approach involves the use of a cross-shelf model to look at the role of the density flows in creating the observed flood deposits on the mid-shelf. This model is relatively simple as it is based on a depth integrated sediment concentration in the wave boundary layer. It only accounts for gravity forced flow of sediment trapped in the wave boundary layer, and other cross shelf transport process are neglected. Thus, it can be used to examine the role of this process alone. A more comprehensive modeling effort, which involves the competing roles of a multitude of transport processes in a fully 3-d numerical model, is proposed by Geyer et al. for 2001-2002. An additional component of the modeling effort involves using vertical resolving, turbulence closure models to examine the detailed vertical structure of the gravity flows. These models were adapted by adding gravitational forcing to existing 1-d sediment transport models developed by P. Wiberg and C. Reed.

WORK COMPLETED

A major task completed in 1999 was the publication of "The Role of Wave-Induced Density-Driven Fluid Mud Flows for Cross-Shelf Transport on the Eel River Continental Shelf." This paper describes the observations from the 1997-98 deployment. The paper examines the events on the inner shelf which lead to the formation of fluid mud layers observed at the mid shelf deposit region. The observations of down-slope flows of fluid mud are described in detail with analysis of the dynamics of the forcing mechanisms for these layers.

The modeling effort is progressing well. The across shelf model was developed and results were presented at several STRATAFORM workshops. Gravitational forcing has been incorporated into 1-d sediment transport models developed by P. Wiberg and C. Reed, and analysis of the results relative to observed data is underway.

RESULTS

The primary result of the aforementioned publication has been to document the presence of down-slope flow of fluid mud as an important mechanism for transporting sediment from the inner shelf, where it is placed by the Eel river plume, to the deposit region located mid shelf. These down-slope flows were observed with an acoustic backscattering sensor (ABS) and a vertical array of current meters. The ABS also showed that depositional events of up to 13 cm were associated with these flows. In fact, all the depositional events observed at the tripod location were associated with fluid mud flows. Erosional events of up to 6 cm were observed during periods of dominantly along-shore transport of low concentration suspended sediment. Thus, it is hypothesized that these fluid mud flows are the mechanism which produces the mid-shelf mud deposit. The cross-shelf transport model (Fig 1) predicts a flood deposit thickness that is (a) consistent with the observed ABS data, and (b) at a location that is consistent with the observed location based on coring work in previous years. Despite the observed depositional events in the 1998 ABS record, a recognizable flood deposit was not

observed in coring work later that year. This indicates the subsequent storm events, after the tripod deployment, but before coring work, were able to resuspend and transport the deposited sediment and erode the deposit. This combination of deposition due to gravity flows and erosion, perhaps due to resuspension by waves and transport by mean currents, will be further examined and modeled in the work proposed by Geyer et al. Understanding the relative roles of these competing processes is key to determining the preservation potential of flood deposit layers on the annual time scale.

In regards to the 1-d modeling effort, testing the results of these models against the vertical profiles of sediment concentration from the ABS and velocity profiles from the electromagnetic current meter array has revealed important insights into the role of density stratification at the top of the wave boundary layer in reducing drag to allow the flow to maintain a large offshore velocity. These detailed models combined with the observations can also be used to validate simpler models for gravity flow that can be incorporated into large and/or longer scale shelf stratigraphy modeling efforts.

IMPACT

The principle impact of this work is to reveal, through observations and modeling, the role of gravity forced fluid mud flows trapped within the wave boundary layer as an important cross-shelf transport mechanism during periods of high riverine sediment supply. The observations and modeling also show that this mechanism is able to explain both the magnitude and location of the initial flood deposits, but is not able to determine the potential for preservation. This is particularly significant since before this study gravity was not thought to play an important role on shelves that were too flat to generate self-suspending turdity currents. This study has shown that turbulence supplied by wave energy combined with the high concentrations of sediment in the wave boundary layer allows significant gravitationally forced flows.

TRANSITIONS

The results of this study have helped steer the modeling efforts of other STRATAFORM investigators studying shelf transport and deposition processes. In particular C. Friedrich and D. Wright's group at VIMS is developing analytical models to predict cross shelf transport based on gravitation forcing of fluid mud in the wave boundary layer.

RELATED PROJECTS

The STATAFORM project provides a unique opportunity to study sediment dynamics in an environment that is dominated by fine sediment during periods of high river discharge. This project provides a sharp contrast to our work in other environments, such as LEO-15 with medium-to-coarse grained sand [*Traykovski et al.*, 1998]. Yet, in both environments it has become apparent that adequately observing sediment concentration and velocity (to calculate transport) in the 10 cm nearest the seafloor is crucial to understanding the dominant mechanisms of sediment transport.

This work is also related to the plume studies performed by R. Geyer. The data collected during this project was used to study the dynamics of the Eel river plume during floods, and the combined modeling of the plume processes and the boundary layer processes is beginning to provide a source-to-deposit view of margin sediment transport.

REFERENCES/PUBLICATIONS

Cacchione, D.A., P.L. Wiberg, J. Lynch, J. Irish, and P. Traykovski, "Estimates of suspended sediment flux and bedform activity on the inner portion of the Eel River continental shelf." *Mar. Geol*., 154,83-97, 1999.

Traykovski, P., A.E. Hay, J. Irish, and J. Lynch, "Geometry, migration, and evolution of wave orbital ripples at LEO-15." *Jour. Geophys. Res*., 104(C1), 1505-1524, 1999.

Traykovski, P. W.R. Geyer, J.D. Irish, J.F. Lynch, "The Role of Density Driven Fluid Mud Flows for Cross Shelf Transport on the Eel River Continental Shelf" In Press, *Cont. Shelf Res.*

Geyer, W.R., P. Hill, T. Milligan, P. Traykovski, "The Structure of the Eel River Plume During Floods," In Press, *Cont. Shelf Res.*

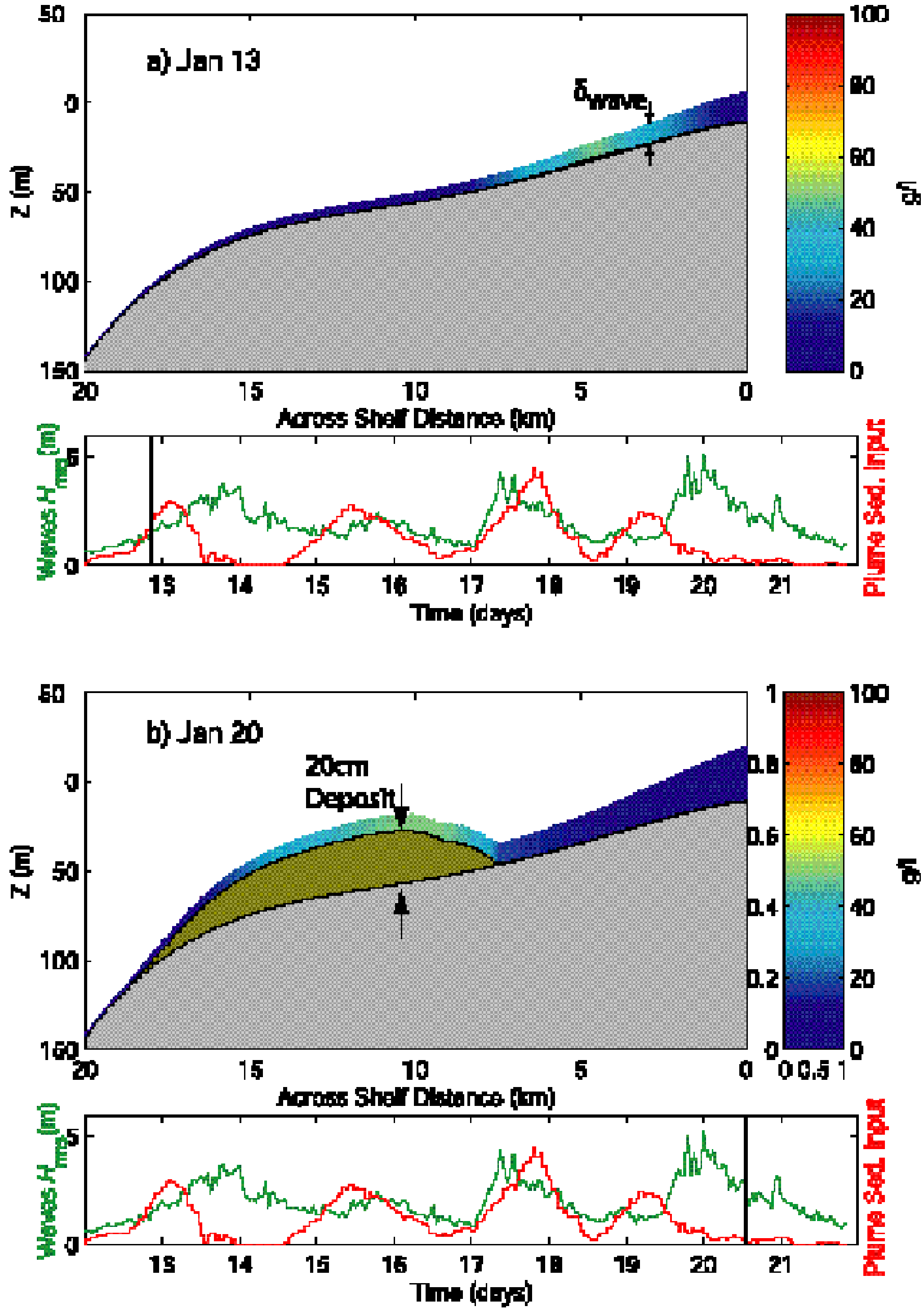

Figure 1 Results from the cross shelf model. Vertical scales for the wave boundary layer thickness (δ_{wave}) and the deposit thickness are exaggerated by 200%. The beginning of the event is shown in (a) where high sediment concentrations can be seen on the inner shelf as sediment settles out of the plume and into the wave boundary layer. The end of the event is shown in panel (b), where a deposit of 20 cm thickness is evident on the mid-shelf (50-100m depths). The highest concentrations are now over the mid-shelf since the sediment from the flood events of the previous days has been transported across the shelf by the density flow in the wave boundary layer.